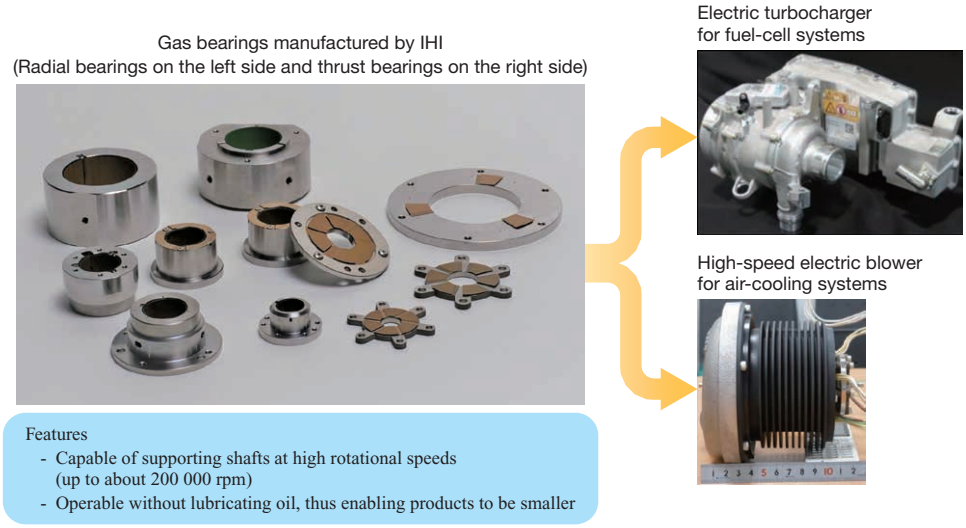
Realizing Lightweighting in Electric Turbomachinery with Gas Bearings

Gas bearings that can be used under heavy load, low ambient pressure and various other conditions without the use of oil

Oil-lubricated bearings require devices that allow oil to circulate, while gas bearings do not. Using gas bearings makes it possible to significantly reduce the weight of electric turbomachinery mounted in aircraft and fuel-cell vehicles. IHI is developing gas bearings that can be used under heavy load, low ambient pressure and various other conditions, thereby contributing to the realization of carbon neutrality of transportation equipment.



Various kinds of IHI gas bearings and their applications to products

The electrification of turbomachinery

Toward the realization of carbon neutrality by 2050, turbomachinery for transportation equipment is becoming increasingly electrified. Conventional turbomachinery uses oil-lubricated bearings to support rotating shafts and thus requires pumps, pipes, tanks, and other devices for oil circulation. Systems having such devices are heavy and this has been an issue in terms of the fuel consumption of transportation equipment, such as aircraft and fuel-cell vehicles. It can be said that making electric turbomachinery lighter to reduce the fuel consumption of transportation equipment is a big challenge.

IHI is working on the development of gas bearings (thrust bearings and radial bearings), which use air or other gas to support rotating shafts. Gas bearings require no oil at all and thus require no oil-circulation devices, so using gas bearings makes it possible to achieve significant reductions in the weight of turbomachinery. In line with the trend of electrifying transportation equipment, IHI has been developing electric turbomachinery equipped with gas bearings, such as electric turbochargers for fuel-cell systems and high-speed electric blowers for air-cooling systems. In line with progress in the electrification of transportation equipment in the future, it is expected that electric turbomachinery with gas bearings will be used in equipment that requires high power, such as the main equipment of aircraft as well as trucks and other large commercial vehicles.

Technological features of gas bearings

The principle of a gas bearing is described here. A gas bearing uses air to lift the target to be supported, just like an air hockey table or a hovercraft. The air hockey table blows air against the bottom of a puck through tiny holes in the surface of the table to cause the puck to float in a contactless and low-friction state. Similarly, a gas bearing forms an air film in a gap with a rotating shaft. When the rotating shaft rotates, the gas bearing draws in air by itself to form the air

film. In other words, the gas bearing works because of the dynamic pressure and does not require a pump or any other device to supply air from the outside. This means that it becomes possible to achieve significant reductions in the weights of systems by using gas bearings.

On the other hand, gas bearings are not good at supporting heavy loads. Generally, the higher the viscosity of a fluid becomes, the more easily a bearing can maintain a lubricating film. However, gas bearings use air, which has a viscosity that is about a thousandth of that of oil. When a gas bearing is subject to a heavy load, it cannot maintain the air lubrication film and so cannot avoid contact with the rotating shaft. High-power electric turbomachinery has a heavy rotating shaft and a high working pressure, and thus requires gas bearings that can resist heavy loads. We are making efforts to improve the load capacities of gas bearings in order to create high-power and lightweight electric turbomachinery.

Developments for adapting gas bearings to high-power motors

Gas bearings have load limits (load capacities) below which they can maintain air films. When electric turbomachinery is in operation, gas bearings may be momentarily subject to heavy loads exceeding their load capacities. To adapt them to high-power motors, we conducted the following developments.

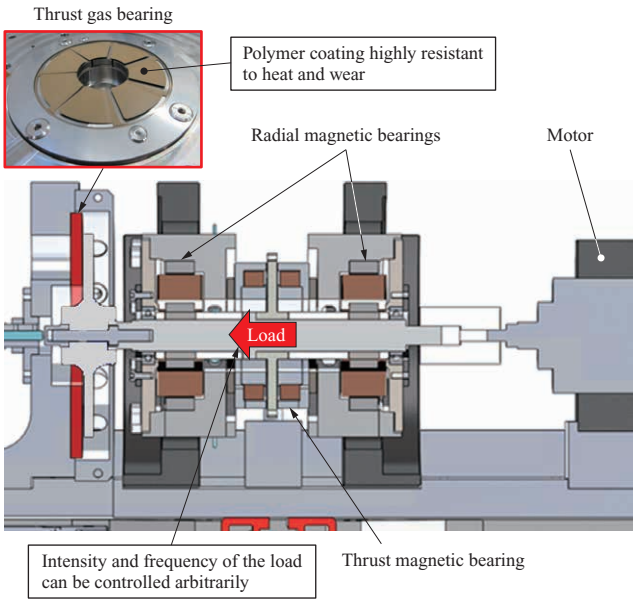
Motors for electric turbomachinery operate at speeds in the tens of thousands of revolutions per minute, and they are equipped with gas bearings that can work under such conditions. It is difficult for commercially available measuring instruments to measure the load capacity of a gas bearing and the bearing power loss while rotating at a high rotational speed under any given load. In view of this, we began by developing a test rig for evaluating the performance of a gas bearing. This test rig has magnetic bearings as a mechanism for controlling the motion of the shaft. The magnetic bearings support the rotating shaft in a non-contact manner with the controlled attraction of electromagnets. The test rig was designed so that these magnetic bearings can be controlled to apply any load to the gas bearing for any duration via the shaft at a high rotational speed. By using this test rig, we determined the load limit (load capacity) below which the IHI gas bearing can maintain the air film. In addition, we developed a tool for predicting the thickness and pressure distribution of the air film and improved the load capacity of the bearing to allow it to support a heavier load. As a result, this bearing was proved to have a load capacity of 400 kPa, though it is said that an ordinary gas bearing can support a load of about 140 kPa.

Unlike stationary machinery, electric turbomachinery for transportation equipment is momentarily subject to vibrations due to abrupt accelerations of the transportation equipment and external impacts, for example. When that happens, bearings may be momentarily subject to loads exceeding their load capacities. In consideration of this possibility, we conducted a test by using the test rig mentioned earlier. The test rig was used to momentarily give the IHI gas bearing a load much higher than its load capacity to intentionally bring it into contact with the rotating shaft. When testing the gas bearing, we provided it with a polymer coating excellent in heat resistance and wear resistance in order to prevent the gas bearing from seizing and improve its durability. The results of the test showed that momentary contacts lasting several tens of milliseconds caused no damage to the bearing even under severe conditions with a surface pressure of 800 kPa at a tip speed of 250 m/s. This demonstrated that the IHI gas bearing has high resistance to vibrations that occur in transportation equipment.

For realizing carbon neutrality

In addition to the developments described above, we are engaged in developments to establish design technologies that allow gas bearings to work in various environments. As one of these developments, we established a system for evaluating the performance of gas bearings under low ambient pressure conditions, and started evaluations. We already demonstrated that the IHI gas bearings can support rotating shafts at about 0.2 atm, which corresponds to the altitude at which aircraft cruise. We are also evaluating the performance under the effects of factors such as entry of moisture and freezing. By acquiring design technologies that allow gas bearings to work in various environments, we will further develop electric turbomachinery equipped with gas bearings, thereby reducing their weights, with the aim of reducing the fuel consumption of transportation equipment and thereby making a great contribution to the realization of carbon neutrality.

This article is based on the results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).



Bearing test rig (Setup for evaluation of thrust bearings)